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**(54) Lining of tubular structures**

(57) A tubular structure, e.g. a tunnel or sewer, is lined by the use of a tubular lining assembly comprising an inflatable tube and curable resin material. The resin material may be light curable, in which case it may surround an inflatable tube of light transmissible material which is cured by the provision of light in the tubular lining assembly when inflated. To

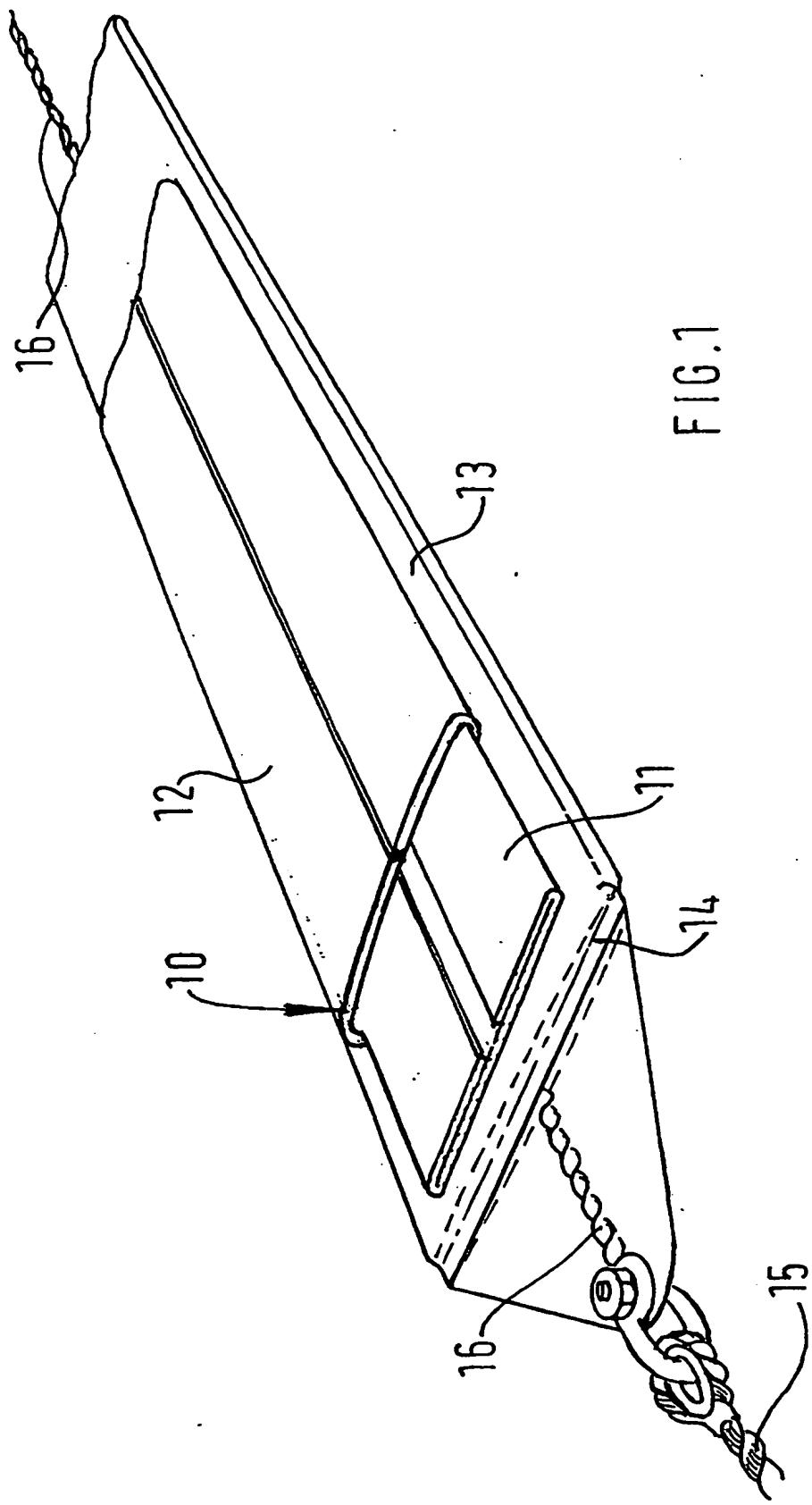
position the tubular lining assembly in a tubular structure use may be made of an evaginable carrier. The lining may be laid on the carrier which is then pulled into position, subjected to at least partial inflation, and then evaginated to permit removal thereof with the inflatable lining assembly remaining in the required position in the tubular structure. The lining assembly may then be inflated and cured.

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FIG. 1



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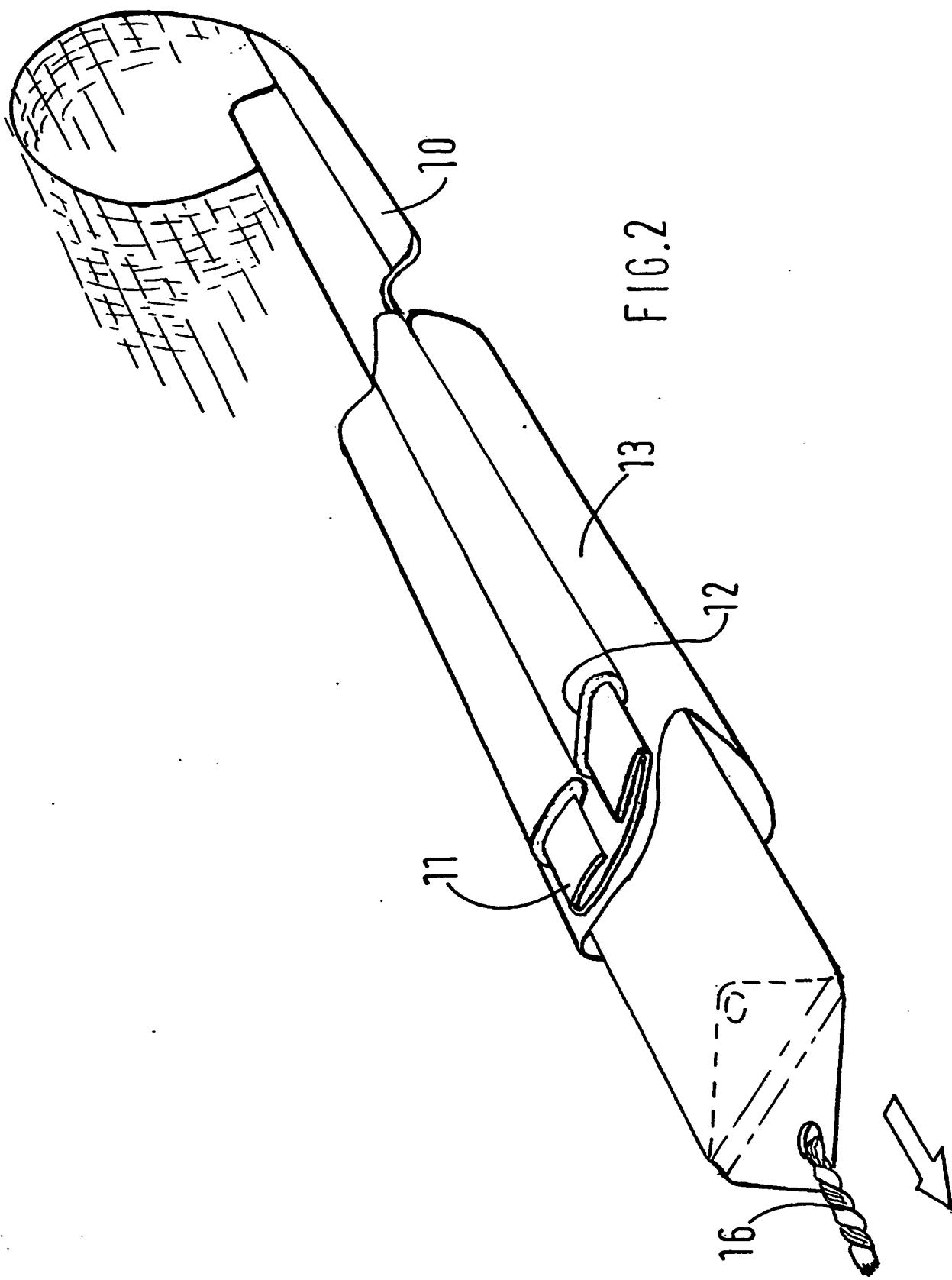


FIG.2

**SPECIFICATION**  
**Lining of tubular structures**

This invention relates to a method of and means for forming a lining in a preformed tubular structure, and in particular, though not exclusively, to the lining of tunnel-type structures such as sewers.

- Many underground tunnels in the U.K. and overseas, and especially those used as sewers, 10 were constructed some 80 to 150 years ago and it is now found that although the bricks used in construction of the tunnels are still in sound condition in many instances the mortar between the bricks is severely eroded.
- 15 In consequence of this erosion a tunnel's ability to withstand external ground pressure is substantially reduced and frequently a localised length of tunnel will collapse thus resulting in much inconvenience and the need for extensive 20 and urgent repair work.

To guard against inadvertent collapse the brickwork can be re-pointed but this is a very time consuming and expensive operation, particularly for the smaller of the man entry type tunnels in 25 which working space is very restricted.

- The alternative approach of forming a new lining within the tunnel has the potential 30 advantage of facilitating provision of a smooth surface having low fluid flow resistance, and also of reducing the requirement for extensive manual work within the restricted space of a tunnel. However, in the current known lining techniques, the lining structure is relatively expensive, or time consuming to install, or there is a requirement for 35 extensive ground excavation at intervals along the length of the tunnel in order to facilitate manoeuvring of the lining structure into the tunnel.

Furthermore, many of the currently known 40 techniques for forming a new lining are unsuitable for the lining of tunnels which are too small to permit man entry.

The present invention seeks to provide a 45 method of lining a tunnel in which the aforesaid difficulties are mitigated or overcome.

In accordance with one aspect of the present 50 invention a method of lining a tubular structure comprises:—

- providing a tubular lining assembly comprising an inflatable tube of light transmissible material surrounded by light curable resin material; drawing said tubular lining assembly into the tubular structure;
- 55 effecting inflation of the tubular lining assembly; and
- introducing a source of light into the inflated tubular lining assembly to effect cure of said light curable resin material.
- 60 Preferably a layer of barrier material is provided between the inflatable tube and the light curable resin material. Subsequent to cure of the resin material the inflatable tube or both the inflatable tube and the barrier material may be removed.

- 65 It is further preferred that the tubular lining assembly is supported on a carrier whilst being drawn into the tunnel structure. The carrier may be an elongated strip-like structure or, the carrier may be a liquid which part fills the tunnel structure 70 such that with partial inflation the inflatable tube can be floated into position.
- In accordance with another aspect of the present invention a method of lining a tubular structure comprises:—
- 75 providing a tubular lining assembly comprising an inflatable tube and curable resin material; supporting said tubular lining assembly on an evaginable carrier; drawing said carrier and tubular lining assembly 80 into the tubular structure; effecting at least partial inflation and then evagination of the carrier to permit removal thereof from the tubular structure with the tubular lining assembly remaining in the tubular structure; 85 and
- effecting inflation of the lining assembly and cure of the curable resin material.
- Preferably said tubular lining assembly 90 comprises an inflatable tube of light transmissible material surrounded by light curable resin material, cure of the lining assembly being effected by providing a light source inside the tubular assembly subsequent to inflation thereof.
- In accordance with another aspect of the present invention a lining for a tubular structure comprises an inflatable tube of light transmissible material surrounded by light curable resin material. Preferably the light curable resin material is surrounded by a layer of material at least the inner surface of which provides good reflection of light.
- The inflatable tube should possess sufficient strength, and if necessary be reinforced, so as to be able to withstand an inflation pressure which is 105 sufficient to counteract the weight of the tube with the curable resin material, and a light reflective layer where provided.
- The evaginable carrier may be presealed at one end, and draw means is secured to said end and 110 extends internally along the length of the carrier to the other end thereof. Subsequent to partial inflation of the carrier said draw means facilitates evagination.
- The draw means which lies internally may be 115 attached to either end of the evaginable carrier so that the carrier may be withdrawn by evagination either in the same or opposite direction to that in which it was originally drawn into the tunnel.
- Preferably two draw means are provided, which 120 may be of similar length, and are arranged such that one extends within the carrier and the other externally.
- The draw means which lies externally facilitates drawing of the carrier and inflatable tubular assembly into the tubular structure but is removed 125 prior to evagination.
- One embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 shows in perspective an end portion of a tubular assembly and evaginable carrier in accordance with the present invention, and

5 Figure 2 shows the tubular assembly and carrier during evagination.

A tubular lining assembly 10 for lining a tunnel comprises, internally, an inflatable tube 11 of light transmissible material such as clear p.v.c. or clear polyethylene. This tube has a peripheral dimension 10 substantially the same as that of the tunnel.

The inflatable tube 11 is surrounded by a pre-impregnated uncured layer 12 of resin and glass composite of a thickness and density which provides the required strength in the finished 15 lining. A layer of clear barrier material such as Melinex (not shown) may be provided between the tube 11 and layer 12 so as to ensure that the tube 11 does not become bonded to the resin and glass composite and may therefore be removed after 20 cure. Subsequently, when desired, the Melinex may also be removed.

The resin and glass composite preferably comprises isophthalic type of resin etc., a suitable pre-impregnant being chopped strand glass mat, 25 woven glass roving, woven glass cloth or a combination thereof.

The uncured composite layer 12 is surrounded by a thin aluminium foil layer (not shown) to provide reflection of light transmitted through the 30 layer 12.

For drawing the lining assembly 10 into a tunnel there is provided an inflatable tubular carrier 13, in the form of a slip liner, of flexible reinforced laminate material such as neoprene-35 nylon-neoprene.

An end 14 of the carrier is sealed and locally reinforced for attachment thereto of a tow rope 15 extending externally of the carrier and an inverting rope 16 which extends internally of the carrier.

40 To line a tunnel the tubular lining assembly 10 is laid on the carrier 13 in the manner shown in Figure 1.

The assembly 10 is then folded longitudinally along its edges (into the configuration as shown in 45 Figure 2) and the carrier, with the assembly 10 supported thereon is then drawn into the tunnel using the tow rope 15.

With the carrier and tubular assembly having been drawn to the required position the carrier is 50 partially inflated with air, thus permitting the inverting rope to be pulled therethrough relatively easily and effecting evagination of the carrier.

Figure 2 shows the carrier during evagination, with the tow rope having first been removed so as 55 to avoid any risk of it rubbing against and damaging the tubular lining assembly 10.

Subsequent to evagination of the carrier the lining assembly is left on the tunnel floor and the carrier is removed from the tunnel.

60 The lining assembly is then inflated with air against the tunnel wall and subsequently a tungsten filament or other light source is passed along the inflated lining at a suitable rate to effect cure of the resin/glass composite.

65 If desired, when the lining assembly is fully

cured a settable liquid grout may be introduced, e.g. by injection through suitable holes provided in the lining, so that any voids between the lining and tunnel wall may be filled and any structural

70 deformations in the tunnel wall may be made good.

If it is desired to provide the lining in the vicinity of a tunnel junction, particularly for man entry sized tunnels, the resin/glass composite is initially 75 only partially cured such that although self-supporting in the absence of internal air pressurisation, it can be readily cut.

After de-pressurisation the lining is cut to the required shape at the junction, and final cure then 80 effected by further passage of the light source through the lining. Subsequently the inflatable lining tube, and optionally, the Melinex, is removed.

#### CLAIMS

85 1. Method of lining a tubular structure comprising:—

providing a tubular lining assembly comprising an inflatable tube of light transmissible material surrounded by light curable resin material;

90 drawing said tubular lining assembly into the tubular structure;

effecting inflation of the tubular lining assembly; and

introducing a source of light into the inflated 95 tubular lining assembly to effect cure of said light curable resin material.

2. Method according to claim 1 wherein the tubular lining assembly is supported on a carrier whilst being drawn into the tubular structure.

100 3. Method according to claim 2 wherein said carrier is evaginable.

4. Method according to any one of the preceding claims wherein a layer of barrier material is provided between the inflatable tube

105 and the light curable resin material to resist adhesion between the inflatable tube and curable resin material when cured.

5. Method according to any one of the preceding claims wherein the inflatable tube is

110 removed after cure of the curable resin material.

6. Method according to claim 5 wherein the barrier material is removed after cure of the curable resin material.

7. Method of lining a tubular structure 115 comprising:—

providing a tubular lining assembly comprising an inflatable tube and curable resin material;

supporting said tubular lining assembly on an evaginable carrier;

120 drawing said carrier and tubular assembly into the tubular structure;

effecting at least partial inflation and then

125 evagination of the carrier to permit removal thereof from the tubular structure with the tubular lining assembly remaining in the tubular structure;

and

effecting inflation of the tubular lining assembly

and cure of the curable resin material.

8. Method according to claim 7 wherein cure of

- the tubular lining assembly is effected by providing a light source inside said assembly subsequent to inflation thereof.
9. Method according to claim 7 or claim 8
- 5 wherein evagination of the carrier is effected by pulling on first draw means which extends along the length of the evaginable carrier, internally thereof.
10. Method according to any one of claims 7 to 10 wherein second draw means is provided to facilitate pulling the support carrier, and tubular lining assembly, into the tubular structure.
11. Method according to claim 10 wherein said second draw means is removed prior to
- 15 evagination.
12. Method of lining a tubular structure substantially as hereinbefore described with reference to the accompanying drawings.
13. Lining for a tubular structure comprising an inflatable tube of light transmissible material surrounded by light curable resin material.
- 20 14. Lining according to claim 13 wherein said light curable resin material is surrounded by a layer of material at least the inner surface of which
- 25 provides good reflection of light.
15. Lining according to claim 13 or claim 14 wherein a layer of barrier material is provided between the inflatable tube of light transmissible material and the light curable resin material to resist adhesion therebetween.
- 30 16. Lining for a tubular structure constructed and arranged substantially as hereinbefore described with reference to the accompanying drawings.